Fishery Data Series No. 91-14

Sport Effort and Harvest of Coho Salmon in Afognak Bay and Lagoon, Alaska, 1990

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A creel survey was conducted from 10 August through 10 September 1990 to estimate the sport fishing effort, catch, and harvest of coho salmon *Oncorhynchus kisutch* between the Alaska Department of Fish and Game salmon weir and the subsistence fishing boundary markers in the Afognak Bay, Lagoon, and River sport fisheries. Data from these surveys indicated that sport anglers fished an estimated 3,700 angler-hours and harvested an estimated 3,010 coho salmon. Additionally, 1,016 coho were estimated to have been caught and released. Age 2.1 fish were most abundant in the harvest. The estimated harvest of 3,010 coho salmon occurred below the weir, which documented an inriver passage of 13,380 coho salmon through 17 September when the weir project terminated. Angler characteristic data collected in conjunction with the creel survey indicated that 54 percent of the interviewed anglers were residents and 18 percent of the interviewed anglers were guided.

KEY WORDS: coho salmon, *Oncorhynchus kisutch*, effort, harvest, release, age, Afognak Lagoon, Afognak Island.

INTRODUCTION

The Afognak River, also known as Litnik River, is located on Afognak Island about 40 kilometers (25 air miles) northwest of the town of Kodiak (Figure 1). An adult salmon *Oncorhynchus spp.* counting weir has been operated on the river since 1978. Escapement during the 1980s averaged 67,000 sockeye salmon *O. nerka* and 26,000 pink salmon *O. gorbuscha* (Table 1). Starting in 1984, the weir operated past 1 September in order to count coho salmon *O. kisutch*, and escapements have averaged 10,600 fish. Chum salmon *O. keta* and chinook salmon *O. tshawytscha* occasionally migrate upriver, however, their numbers generally average less than 10 fish annually. There is also a small steelhead *O. mykiss* run, and counts of kelts (steelhead which have overwintered in the lake, spawned in the river in the spring, and migrated downstream after spawning) have averaged 50 fish during the 1980s. The 1990 count of 191 kelts is the largest on record. Dolly Varden *Salvelinus malma* and rainbow trout also inhabit the river. The 1990 escapement of enumerated fish was 90,666 sockeye salmon, 27,808 pink salmon, 13,380 coho salmon, and 191 steelhead kelts (Table 2).

The Afognak system supports commercial, subsistence, and sport fisheries for coho salmon (Table 3). Afognak Lagoon is very popular with sport anglers because it offers the benefits of a remote fishing experience while being easily accessible by boat and plane. Coho salmon often provide excellent fishing as they school up in large numbers and hold in a fishable lagoon area until high water conditions encourage them to migrate to the spawning grounds. Coho directed fishing usually peaks in late August to early September.

Due to the Afognak system's accessibility from the towns of Kodiak and Port Lions and to it's popularity with coho sport fishermen, a creel survey was conducted to estimate the sport harvest and to characterize the fishery. The Alaska Department of Fish and Game (ADFG) plans to continue conducting creel surveys of the larger sport fisheries on a rotating basis so that base line data can be collected to evaluate potential conservation concerns or to identify appropriate regulation changes.

METHODS

Creel Survey

The coho salmon immigration into the Afognak River in 1990 began on 27 July and continued through September (Table 2). Weir operation was discontinued on 17 September. Passage of coho salmon was high during the last 4 days of weir operation. However, based on past experience, it is unlikely that passage after this date was significant. Nevertheless, some additional passage undoubtedly occurred and the weir count is a minimal value. The sport fishery mainly occurs in the lagoon, usually between 10 August and 10 September. Access to the fishery was by boat from the towns of Kodiak, Port Lions, and Ouzinkie.

Observations by weir personnel have shown that the majority of the fishery effort occurs in saltwater areas below the weir (84% in 1987 and 91% in 1988).

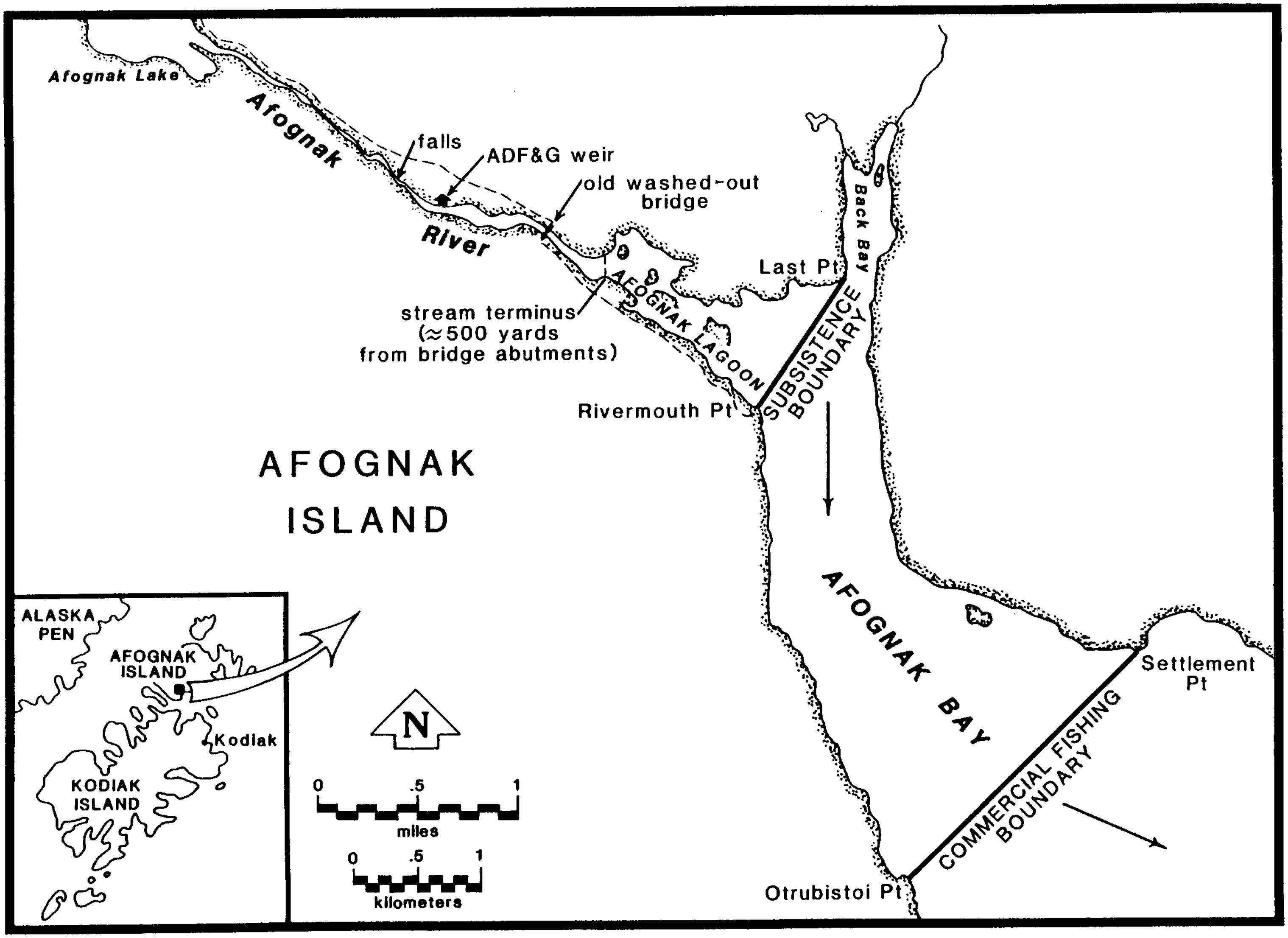

Figure 1. Location map of Afognak Lagoon, Afognak Island, Alaska.

Table 1. Afognak River weir escapement counts, 1978-1990.[a]

	Sockeye Salmon	Steelhead kelts[b]	Pink Salmon	Coho Salmon[c]	Chum Salmon	Steelhead[d]
1978	52,701		56,749	6,881 (9/14)	13	
1979	88,770		4,755	4,920 (8/20)	2	
1980	93,806		11,508	433 (8/31)	4	
1981	57,267	3	4,135	4,271 (8/26)	3	
1982	123,055	106	3,841	428 (8/25)	0	
1983	40,049	2	5,239	112 (8/10)	0	1
1984	94,463	27	30,463	7,732 (9/21)	0	41
1985	53,872	60	2,215	13,847 (9/29)	2	136
1986	48,333	134	68,052	5,082 (9/27)	6	
1987	26,474	126	8,780	11,469 (9/29)	16	64
1988	39,012		148,206	9,972 (9/9)	11	28
1989	88,825	20	41,611	13,050 (9/20)	9	120
1990	90,666	191	27,808	13,380 (9/17)	0	61

[a] The first year of weir operation was 1978. The weir was moved downriver from the lake to the lagoon on 22 August 1986.

[b] Kelts are trapped which have overwintered in the lake, spawned, and are running to the sea.

[c] Date in ( ) represents the last day the weir was operated each year.

[d] Steelhead: Partial count of upstream migrating fish that over-winter in the lake, since significant migration occurs after the weir is removed.

Table 2. Cumulative escapement of salmon and steelhead, Afognak River weir, 1990.

Date		Sockeye Salmon	Steelhead	Pink Salmon	Coho Salmon
May	27	38			
	28	126			
	29	443			
	30	903			
	31	1,423			
June	1	1,786			
	2	2,695			
	3	3,925	53[a]		
	4	6,417	53		
	5	8,804	57		
	6	9,837	61		
	7	14,220	84		
	8	15,203	86		
	9	17,771	122		
	10	21,116	130		
	11	24,798	132		
	12	26,055	132		
	13	36,358	170		
	14	42,520	175		
	15	45,862	176		
	16	46,475	182		
	17	46,967	185		
	18	48,915	185		
	19	52,259	185		
	20	57,494	186		
	21	60,679	186		
	22	61,696	186		
	23	62,039	187		
	24	62,882	188		
	25	63,818	188		
	26	65,271	188		
	27	65,566	188		
	28	66,207	188		
	29	66,449	188		
	30	66,673	188		
July	1	67,208	189		
	2	68,937	189		
	3	69,328	189		
	4	69,999	189		
	5	70,073	189		
	6	71,258	189		

-Continued-

Table 2. (Page 2 of 3).

Date	Sockeye Salmon	Steelhead	Pink Salmon	Coho Salmon
July 7	72,063	189		
8	72,592	189		
9	74,966	191		
10	75,651		1	
11	76,164		1	
12	76,507		1	
13	76,686		1	
14	78,696		3	
15	78,768		3	
16	79,485		3	
17	79,485		3	
18	79,601		5	
19	79,961		5	
20	80,281		6	
21	80,426		6	
22	82,484		22	
23	82,547		27	
24	82,689		27	
25	82,834		27	
26	83,047		28	
27	85,133		91	3
28	86,975		461	7
29	87,543		549	7
30	87,697		562	7
31	87,992	1[b]	655	9
Aug. 1	88,798	4	1,344	15
2	89,014	5	1,494	19
3	89,203	5	1,817	23
4	89,371	7	2,130	39
5	89,467	7	2,255	48
6	89,508	7	2,378	68
7	89,598	11	3,502	190
8	89,700	11	5,497	343
9	89,755	15	6,969	455
10	89,794	16	7,264	472
11	89,962	21	8,899	862
12	90,003	23	9,553	1,037
13	90,009	23	10,323	1,157
14	90,063	23	11,258	1,319
15	90,129	23	12,439	1,478
16	90,200	23	15,726	1,765
17	90,231	23	18,692	2,355

-Continued-

Table 2. (Page 3 of 3).

Date	Sockeye Salmon	Steelhead	Pink Salmon	Coho Salmon
Aug. 18	90,259	23	18,996	2,483
19	90,291	24	20,443	2,912
20	90,323	28	21,659	3,573
21	90,354	31	22,159	4,070
22	90,366	32	22,405	4,331
23	90,384	33	22,660	4,564
24	90,404	34	22,977	4,936
25	90,421	36	23,159	5,316
26	90,430	37	23,219	5,375
27	90,453	40	23,321	5,449
28	90,458	40	23,389	5,487
29	90,460	42	23,399	5,491
30	90,460	42	23,413	5,497
31	90,461	42	23,505	5,516
Sep. 1	90,469	42	23,660	5,556
2	90,474	46	23,759	5,631
3	90,494	46	24,430	6,117
4	90,500	46	24,697	6,514
5	90,503	46	24,838	6,534
6	90,505	46	24,934	6,544
7	90,509	46	25,308	6,596
8	90,515	46	25,890	6,625
9	90,518	46	26,256	6,653
10	90,520	46	26,332	6,653
11	90,522	46	26,727	6,665
12	90,527	46	27,258	7,400
13	90,527	46	27,313	7,406
14	90,640	55	27,690	11,052
15	90,640	56	27,696	11,061
16	90,666	61	27,808	12,130
17	90,666	61	27,808	13,380

[a] Adult steelhead migrating downstream (kelts).

[b] Adult steelhead migrating upstream.

Table 3. Commercial and subsistence harvest of salmon in Afognak Bay (statistical area 252-34), 1978-1990.

	Commercial Harvest				Subsistence Harvest			
Year	Sockeye	Pink	Coho	Chum	Sockeye	Pink	Coho	Chum
1978	3,414	100	1,689	25	781	0	194	0
1979	2,146	2,504	6,147	120	1,099	73	231	3
1980	38	57,102	5,186	692	1,870	56	175	7
1981	16,990	11,344	2,515	3,159	1,431	52	400	3
1982	21,622	13,908	10,935	1,066	3,425	128	1,178	12
1983	4,399	8,471	1,560	1,945	3,121	66	934	17
1984	6,130	15,369	1,816	377	6,804	92	1,132	14
1985	1,980	2,683	2,062	61	4,067	211	1,415	19
1986	2,585	8,055	462	566	3,457	339	1,218	34
1987	1,323	2,047	286	109	2,464	132	985	4
1988	14	6,357	545	134	2,253	27	359	13
1989[a]					3,758	94	272	25
1990[b]	22,149	23,450	903	1,790	3,575	19	549	3

[a] No commercial harvest in 1989 due to the Exxon-Valdez oil spill.

[b] Preliminary.

For this reason the survey was designed to accurately estimate the saltwater harvest below the weir. Fishery monitoring during previous years has also shown that approximately 90% of the fishing effort occurs between 10 August and 10 September. In 1990, the survey was conducted over this time period (Table 4). During 1990, anglers were permitted a daily bag and possession limit of five coho salmon 508 mm (20 inches) in length or greater.

Study Design:

The survey was conducted as a roving creel survey (Neuhold and Lu 1957). Over the month of the survey, 5 days were randomly chosen for sampling every week. The last sampling week contained 4 days, and 2 of these were sampled.

The fishing day was defined as 0700 to 2200 hours, and each day was divided into five 3-hour periods:

Period	Time
A	0700-0959
B	1000-1259
C	1300-1559
D	1600-1859
E	1900-2200

Two sample periods were randomly selected on each survey day.

Two angler counts were made during each survey period. Angler counts took approximately 5 minutes to complete and were considered to be instantaneous counts. Six starting times for angler counts were assigned at the start of each half hour. The first count was randomly scheduled for one of the first three possible starting times. The second was systematically placed 1 hour and 30 minutes later. The angler counts began at a randomly selected (by a coin toss) end of the fishery at the count time scheduled. The technician proceeded at a constant rate of travel to the opposite end of the fishery while counting anglers actively engaged in fishing (Tables 5 and 6).

The creel technician attempted to gather as many interviews as possible from anglers who had completed fishing for the day; however, anglers who were still fishing were also interviewed. The following information was obtained from each angler interviewed: number of hours fished, number of fish harvested and released by species, and angler characteristics.

Data Analysis

Angler effort, catch, and harvest, their associated variances, and standard errors were estimated for the creel survey. A systematic-random estimator was used to estimate angler effort on a sample by sample basis. Catch and harvest estimates for each sample were obtained by a ratio estimator by combining the estimated effort (for the sample) with estimates of catch per unit effort (CPUE) and harvest per unit effort (HPUE) obtained from the angler interviews. The CPUE and HPUE estimates were obtained by the jackknife estimation approach (Efron 1982). The jackknife approach for estimating CPUE and HPUE was used

Table 4. Estimates of sport effort, catch, and harvest, Afognak River and Lagoon, from 10 August through 10 September 1990.

Total number of days	32
Effort	
Days sampled	22
Mean angler hours/day	116
Total angler hours	3,700
S_{1h}^2	13,451
Variance components	
Stage 1	195,657
Stage 2	61,807
Stage 3	21,977
Total Variance	279,442
Relative Precision (α = 0.05)	28%
Catch	
Days sampled	22
Mean catch/day	126
Total catch	4,026
S_{1h}^2	22,030
Variance components	
Stage 1	320,439
Stage 2	134,175
Stage 3	51,669
Total Variance	506,283
Relative Precision (α = 0.05)	35%
Harvest	
Days sampled	22
Mean harvest/day	94
Total harvest	3,010
S_{1h}^2	9,429
Variance components	
Stage 1	137,153
Stage 2	47,504
Stage 3	26,186
Total Variance	210,842
Relative Precision (α = 0.05)	30%

Table 5. Daily statistics for Afognak River and Lagoon coho salmon creel survey, 1990.

Date	WE/ WD[a]	Period[b]	Mean Count	Total Effort[c]	Variance Effort	Number of Interviews	CPUE	Variance CPUE	Total Catch	Variance Catch	HPUE	Variance HPUE	Total Harvest	Variance Harvest
900812	1	B	0.0	0	0	0								
900812	1	D	7.0	35	1,225	14	0.152	0.014	5	28	0.152	0.014	5	28
900813	2	B	6.5	33	56	3	0.444	0.086	14	98	0.333	0.111	11	117
900813	2	C	12.5	63	506	7	0.323	0.007	20	78	0.323	0.007	20	78
900814	2	A	0.0	0	0	0								
900814	2	C	2.5	13	56	8	0.344	0.112	4	18	0.344	0.112	4	18
900815	2	C	1.0	5	25	2	0.125	0.016	1	0	0.000	0.000	0	0
900815	2	E	0.0	0	0	0								
900816	2	B	0.0	0	0	0								
900816	2	C	0.0	0	0	0								
900817	2	A	0.0	0	0	0								
900817	2	E	0.0	0	0	0								
900818	1	A	0.0	0	0	3	0.000	0.000	0	0	0.000	0.000	0	0
900818	1	C	7.5	38	6	10	0.300	0.018	11	25	0.300	0.018	11	25
900820	2	A	1.5	8	56	0								
900820	2	B	5.5	28	156	7	0.344	0.015	9	28	0.344	0.015	9	28
900821	2	B	1.5	8	56	0								
900821	2	C	10.5	53	156	8	0.339	0.063	18	181	0.339	0.063	18	181
900823	2	A	4.0	20	400	7	1.983	0.278	40	1,573	1.270	0.164	25	646
900823	2	E	2.0	10	0	1	1.500	0.000	15	0	1.500	0.000	15	0
900824	2	A	1.5	8	56	3	1.333	0.028	10	100	1.333	0.028	10	100
900824	2	D	0.5	3	6	1	1.000	0.000	3	6	1.000	0.000	3	6
900825	1	B	0.0	0	0	0								
900825	1	D	11.0	55	25	5	1.008	0.015	55	71	0.723	0.025	40	88
900826	1	B	13.5	68	156	7	1.543	0.019	104	453	1.000	0.000	68	156
900826	1	C	12.0	60	0	4	0.250	0.009	15	33	0.250	0.009	15	33
900828	2	B	8.0	40	0	0								
900828	2	C	10.5	53	6	12	0.581	0.018	31	53	0.581	0.018	31	53

-Continued-

Table 5. (Page 2 of 2).

Date	WE/ WD[a]	Period[b]	Mean Count	Total Effort[c]	Variance Effort	Number of Interviews	CPUE	Variance CPUE	Total Catch	Variance Catch	HPUE	Variance HPUE	Total Harvest	Variance Harvest
900830	2	A	0.0	0	0	0								
900830	2	B	3.5	18	156	7	5.339	0.554	93	4,537	3.304	0.839	58	1,832
900901	1	B	20.0	100	400	13	1.629	0.111	163	2,123	0.876	0.031	88	608
900901	1	D	18.0	90	0	10	1.164	0.018	105	142	0.962	0.023	87	185
900902	1	B	6.5	33	56	8	1.275	0.252	41	344	0.775	0.057	25	91
900902	1	D	1.0	5	25	0								
900904	2	A	3.0	15	225	6	1.604	0.055	24	579	1.604	0.055	24	579
900904	2	D	1.5	8	56	7	1.260	0.653	9	89	1.260	0.653	9	89
900905	2	A	2.5	13	156	6	1.810	0.626	23	512	1.810	0.626	23	512
900905	2	E	0.0	0	0	0								
900906	2	A	0.0	0	0	5	1.369	0.286	0	0	1.369	0.286	0	0
900906	2	D	4.0	20	0	6	0.550	0.012	11	5	0.367	0.006	7	2
900908	1	D	7.5	38	1,406	0								
900908	1	E	7.5	38	56	9	1.059	0.052	40	133	0.612	0.025	23	55
900910	2	A	4.0	20	400	0								
900910	2	B	5.5	28	156	8	1.472	0.132	40	418	1.360	0.155	37	382

[a] Weekend = 1, Weekday = 2.
[b] A = 0700-0959
B = 1000-1259
C = 1300-1559
D = 1600-1859
E = 1900-2200
[c] Angler-hours

Table 6. Number of anglers counted during sample periods[a], Afognak Lagoon, 1990.

		Period				
Week	Date	A (0700-0959)	B (1000-1259)	C (1300-1559)	D (1600-1859)	E (1900-2200)
1	8/10					
	8/11					
	8/12		0 / 0		14 / 0	
	8/13		5 / 8	8 /17		
	8/14	0 / 0		4 / 1		
	8/15			2 / 0		0 / 0
	8/16		0 / 0	0 / 0		
2	8/17	0 / 0				0 / 0
	8/18	0 / 0		7 / 8		
	8/19					
	8/20	0 / 3	3 / 8			
	8/21		0 / 3	13 / 8		
	8/22					
	8/23	0 / 8				2 / 2
3	8/24	0 / 3			1 / 0	
	8/25		0 / 0		10 /12	
	8/26		11 /16	12 /12		
	8/27					
	8/28		8 / 8	11 /10		
	8/29					
	8/30	0 / 0	0 / 1			
4	8/31					
	9/01		16 /24		18 /18	
	9/02		8 / 5		0 / 2	
	9/03					
	9/04	0 / 6			3 / 0	
	9/05	0 / 5				0 / 0
	9/06	0 / 0			4 / 4	
5	9/07					
	9/08				0 /15	9 / 6
	9/09					
	9/10	0 / 8	8 / 3			

[a] Two randomly selected angler counts were conducted during each period.

since most other estimators are known to be biased (for use as ratio estimators, i.e., for expansion). The jackknife estimate has been shown to be less biased and procedures exist for correcting this bias, as noted below (see Cochran 1977, section 6.15, pages 174-177; and Smith 1980).

The individual sample estimates of effort, catch, and harvest were then used in a stratified three-stage estimation approach to obtain total estimates, both within strata and across strata, as noted below.

The first step involved obtaining the jackknife estimated sample mean of CPUE (or HPUE) as follows:

$CPUE^{*}_{hijk}$ = the jackknifed CPUE for angler k in sample j, day i and stratum h;

$$= \frac{\sum_{\substack{o=1 \\ o \neq k}}^{m_{hij}} c_{hijo}}{\sum_{\substack{o=1 \\ o \neq k}}^{m_{hij}} e_{hijo}}; \qquad [1]$$

where:

h = subscript denoting sampling stratum;

i = subscript denoting day sampled;

j = subscript denoting period within day i sampled;

k & o = subscript denoting angler interviewed;

m_{hij} = number of anglers interviewed within sample j, day i, and stratum h;

c_{hijo} = catch of angler o within sample j, day i, and stratum h; and

e_{hijo} = effort in hours of angler o within sample j, day i, and stratum h.

The jackknife mean CPUE for sample j within day i and stratum h was then obtained simply as:

$$\overline{CPUE}^{*}_{hij} = \frac{\sum_{k=1}^{m_{hij}} CPUE^{*}_{hijk}}{m_{hij}}. \qquad [2]$$

Then the bias correction (adapted from Efron 1982, equation 2.8, page 6) was performed:

$$\overline{CPUE}^{*\dagger}_{hij} = [m_{hij} (\overline{CPUE}_{hij} - \overline{CPUE}^{*}_{hij})] + [\overline{CPUE}^{*}_{hij}]; \qquad [3]$$

where:

$\overline{CPUE}_{hij}$ = the standard ratio estimator;

$$= \frac{\sum_{k=1}^{m_{hij}} c_{hijk}}{\sum_{k=1}^{m_{hij}} e_{hijk}}. \qquad [4]$$

The bias-corrected jackknife mean was then expanded by the estimated angler effort for the sample to obtain the estimated catch for sample *j* within day *i* and stratum *h*:

$$\hat{C}_{hij} = \hat{E}_{hij} \overline{CPUE}^{*\dagger}_{hij}; \qquad [5]$$

where:

$\hat{E}_{hij}$ = estimated angler effort (in hours) for sample *j* within day *i* and stratum *h*;

$$= H_{hij} \bar{x}_{hij}; \qquad [6]$$

H_{hij} = number of hours in sampling period *j* within day *i* and stratum *h*;

$\bar{x}_{hij}$ = mean angler count for sample *j* within day *i* and stratum *h*;

$$= \frac{\sum_{q=1}^{r_{hij}} x_{hijq}}{r_{hij}}; \qquad [7]$$

q = subscript denoting the angler count sample;

r_{hij} = the total number of angler counts conducted for sample *j* within day *i* and stratum *h*; and

x_{hijq} = the number of anglers counted fishing during count *q* during sample *j* within day *i* and stratum *h*.

The harvest for the sample was estimated similarly by substituting the appropriate harvest statistics into equations [1] to [5], above.

Estimates of angler effort, catch, and harvest for each day sampled were obtained as follows:

$\hat{\bar{Y}}_{hi}$ = mean of the sample estimates for day *i* within stratum *h*; in which Y represents E, C, or H for effort, catch, and harvest, respectively;

$$= \frac{\sum_{j=1}^{p_{hi}} \hat{Y}_{hij}}{p_{hi}}; \qquad [8]$$

where:

p_{hi} = number of periods sampled within day *i* and stratum *h*; and

$\hat{Y}_{hij}$ = estimated sample value for effort (E, as obtained from equation [6], above), catch or harvest (C or H, as obtained from equation [5], above).

The estimated daily effort, catch, and harvest were obtained by expanding by the number of sampling periods in the day:

$\hat{Y}_{hi}$ = estimate for day *i* within stratum *h*; in which Y represents E, C, or H for effort, catch, and harvest, respectively;

$$= P_{hi}\ \hat{\bar{Y}}_{hi}; \qquad [9]$$

where:

P_{hi} = number of possible sampling periods within day *i* and stratum *h*.

Similarly, we obtained estimates for each sampling stratum as follows:

$\hat{\bar{Y}}_{h}$ = mean of the daily estimates for stratum *h*; in which Y represents E, C, or H for effort, catch, and harvest, respectively;

$$= \frac{\sum_{i=1}^{d_h} \hat{Y}_{hi}}{d_h}; \qquad [10]$$

where:

d_h = number of days sampled within stratum *h*.

The estimated stratum effort, catch, and harvest were obtained by expanding by the number of days in each stratum:

$\hat{Y}_h$ = estimate for stratum *h*; in which Y represents E, C, or H for effort, catch, and harvest, respectively;

$$= D_h \hat{\bar{Y}}_h; \qquad [11]$$

where:

D_h = number of days within stratum *h*.

The variance of the estimated catch for stratum *h* was obtained by the three-stage variance equation (following the approach outlined by Cochran 1977), omitting the finite population correction factor (FPC) for the third stage units:

$$\hat{V}[\hat{C}_h] = \left\{ (1 - f_{1h}) D_h^2 \frac{s_{1h}^2}{d_h} \right\}$$

$$+ \left\{ f_{1h} D_h^2 \sum_{i=1}^{d_h} (1 - f_{2hi}) P_{hi}^2 \frac{s_{2hi}^2}{d_h^2 p_{hi}} \right\}$$

$$+ \left\{ f_{1h} D_h^2 \sum_{i=1}^{d_h} f_{2hi} P_{hi}^2 \sum_{j=1}^{p_{hi}} \frac{\hat{V}[\hat{C}_{hij}]}{d_h^2 p_{hi}^2} \right\}; \qquad [12]$$

where:

f_{1h} = sampling fraction for days;

$$= \frac{d_h}{D_h} \qquad [13]$$

S^2_{1h} = the among day variance for the total angler catch estimate over all days sampled in stratum *h*;

$$= \frac{\sum_{i=1}^{d_h} (\hat{C}_{hi} - \hat{\bar{C}}_h)^2}{d_h - 1}; \qquad [14]$$

f_{2hi} = sampling fraction for periods within each day;

$$= \frac{p_{hi}}{P_{hi}} \qquad [15]$$

S^2_{2hi} = the among period variance for day *i* in stratum *h*;

$$= \frac{\sum_{j=1}^{p_{hi}} (\hat{C}_{hij} - \hat{\bar{C}}_{hi})^2}{p_{hi} - 1}; \qquad [16]$$

$\hat{V}[\hat{C}_{hij}]$ = the within period variance for the estimated sample catch for sample *j* within day *i* and stratum *h*, obtained by Goodman's (1960) formula for the variance of a product of independent random variates:

$$= \hat{E}^2_{hij}\, s^{*2}_{3hij} + (\overline{CPUE}^{*\dagger}_{hij})^2\, \hat{V}[\hat{E}_{hij}] - s^{*2}_{3hij}\, \hat{V}[\hat{E}_{hij}]; \qquad [17]$$

s^{*2}_{3hij} = jackknife estimate of the variance for the jackknifed sample mean CPUE for sample *j* within day *i* and stratum *h* (adapted from Efron 1982, equation 3.2, page 13);

$$= \frac{(m_{hij} - 1)}{m_{hij}} \sum_{k=1}^{m_{hij}} (CPUE^{*}_{hijk} - \overline{CPUE}^{*}_{hij})^2; \qquad [18]$$

$\hat{V}[\hat{E}_{hij}]$ = estimated variance of the angler effort estimate for sample *j* within day *i* and stratum *h*, obtained by using the successive differences formula appropriate for systematic samples (adapted from Wolter 1985, equation 7.2.4, page 251);

$$= \frac{H_{hij}^2}{r_{hij}} \frac{\sum_{q=2}^{r_{hij}} \left[x_{hijq} - x_{hij(q-1)} \right]^2}{2\ (r_{hij} - 1)} . \qquad [19]$$

Variance estimates for the estimated harvest were obtained by replacing the appropriate harvest statistics (h's and H's) for the catch statistics (c's and C's) in equations [12] through [18], above.

Stratum estimates of the variance of the angler effort were obtained in a similar manner to those for catch and harvest. The primary difference occurs in the third major term in equation [12]:

$$\hat{V}[\hat{E}_h] = \left[(1 - f_{1h})\ D_h^2 \frac{s_{1h}^2}{d_h} \right] + \left[f_{1h}\ D_h^2 \sum_{i=1}^{d_h} (1 - f_{2hi})\ P_{hi}^2 \frac{s_{2hi}^2}{d_h^2 p_{hi}} \right] + \left[f_{1h}\ D_h^2 \sum_{i=1}^{d_h} f_{2hi}\ P_{hi}^2 \sum_{j=1}^{p_{hi}} \frac{\hat{V}[\hat{E}_{hij}]}{d_h^2 p_{hi}^2} \right] . \qquad [20]$$

The values for the terms in equation [20], were obtained by replacing the catch statistics (C's) by the appropriate effort statistics (E's), in equations [13] through [16] (and equation [19] is used as is in the final term of equation [20]).

Total angler effort, catch, or harvest across all strata (or select combinations of strata) and the associated variances were obtained by the following equations:

$\hat{Y}$ = total estimated angler effort, catch, or harvest, where Y equals the parameter of interest (e.g., E, C, or H for effort, catch, and harvest, respectively);

$$= \sum_{h=1}^{s} \hat{Y}_h \qquad [21]$$

where:

s = number of strata to be combined;

$\hat{Y}_h$ = estimate for the parameter of interest in stratum *h*;

$\hat{V}[\hat{Y}]$ = variance estimate for the estimated total for the parameter of interest, assuming independence of the stratum estimates (see Kish 1965, equation 2.8.7, page 61);

$$= \sum_{h=1}^{s} \hat{V}[\hat{Y}_h]; \text{ and} \qquad [22]$$

$\hat{V}[\hat{Y}_h]$ = variance estimate for the parameter of interest in stratum *h*.

Since our estimates of angler effort, catch, and harvest were estimates of totals, then standard errors (SE's) were obtained as follows:

$$SE(\hat{Y}) = (\hat{V}[\hat{Y}])^{1/2} \qquad [23]$$

Equation [23] was applied to the individual stratum estimates to obtain standard errors for the stratum estimates of effort, catch, and harvest.

Biological Data

A portion of the coho salmon harvested by the sport fishery was randomly sampled for age, sex, and length information. Two scales were collected on the left side of each fish, approximately two rows above the lateral line and on the diagonal row downward from the posterior insertion of the dorsal fin as described in Clutter and Whitesel (1956). Scales were mounted on adhesive-coated cards and impressions were made in cellulose acetate. Age determinations were made by examination of scales using a microfiche reader. Ages were designated using the European method (Koo 1962) where the first number refers to the number of years of freshwater residence after emergence and the second number refers to the number of years of marine residence. For example, a 2.1 fish collected in 1990 was 4 years old and was spawned in the fall of 1986. It spent over one-half year incubating in the gravel, a little over 2 years rearing in fresh water as a fry, and a little over 1 year at sea. Fish lengths were measured from the middle of the eye to fork of the tail to the nearest 0.5 cm.

RESULTS

Creel Survey

The total estimated harvest from 10 August through 10 September was 3,010 coho salmon (Table 4). An additional 1,016 coho salmon were estimated to have been caught and released during this time period. An estimated fishing effort of 3,700 hours were expended.

During the first 13 days of the study fishing was poor (Table 5). Heavy rains and high water caused fish to migrate directly into the river and lake without holding in the lagoon, making them less vulnerable to fishermen. These conditions discouraged fishermen and as a result angler effort was low (Table 6). Harvest and catch rates peaked between 26 August and 2 September. Due to low water conditions in early September, coho held in the lagoon until about 14 September, after which time rains and high water induced fish to migrate to the spawning grounds (Table 2). Almost one-half the escapement (6,000 coho) passed the weir between 14 and 17 September. The creel survey ended on 10 September; however, fishing remained good through 15 September, so additional harvest did occur after the survey ended.

We were concerned that if fishing success during a day was sporadic, use of incomplete-trip angler interviews would bias harvest estimates. To ensure that this was not the case, a comparison of harvest by complete-trip and incomplete-trip anglers was made and is presented in Table 7. There was not a significant difference in angler success between complete and incomplete interviews (Table 7) so both types of interviews were used in the analysis.

Completed-trip interviews were analyzed to examine the effect of bag limits on harvest and effort (Figure 2). Over one half of the harvest was accounted for by anglers who harvested 5 fish per day (Figure 2b). However, these anglers accounted for only 20% of the effort (Figure 2a). Reductions in bag limit would be effective in reducing harvest should conservation measures become warranted (Figure 2c). For example, 11% of the harvest was accounted for by the 5th fish, 26% of the harvest was accounted for by the 4th and 5th fish, etc.

Approximately half (54%) of the interviewed anglers were residents, and only 18% of the fishermen were guided (Table 8). Although harvest estimates were not calculated for other species, the number reported during interviews is presented in Table 9. The number of reported coho salmon harvested is 15 times greater than the next highest reported species.

Biological Data

Coho salmon aged 2.1 made up 84% of the sample taken from the sport fishery (Table 10). Males made up 62% of the sample. Length data are presented in Table 11.

Table 7. Comparison of harvest success between complete-trip and incomplete-trip anglers, Afognak creel survey, from 10 August through 10 September 1990.

Trip type	Number of Anglers with 0 coho	Number of Anglers Who Harvested at Least 1 coho	Percent Successful Anglers[a]
Complete	46	72	61
Incomplete	19	50	72

[a] Chi-square = 2.516 df = 1 $0.10 < P < 0.25$

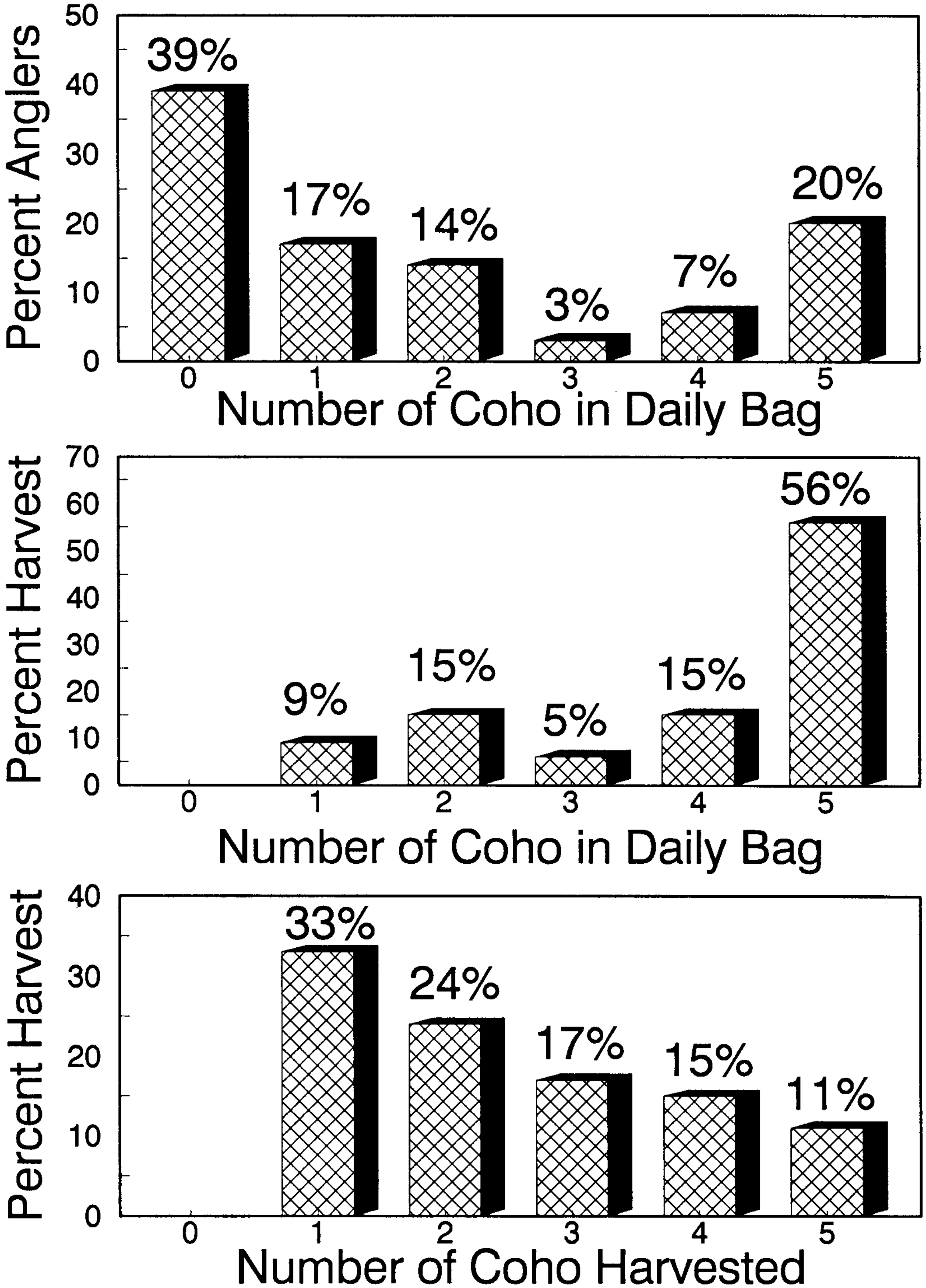

Figure 2. Bag limit analysis for the Afognak River sport fishery, 1990.

Table 8. Characteristics of interviewed anglers, Afognak Lagoon creel survey, from 10 August through 10 September 1990.

	Number of anglers	Percent
Guided	33	18%
Unguided	153	82%
Total	186	
Alaskan Resident	100	54%
Non-resident	86	46%
Total	186	
Local Kodiak Borough Resident	98	98%
Non-local	2	2%
Total	100	
Military	6	3%

Table 9. Catch and harvest by interviewed anglers, Afognak Lagoon creel survey, from 10 August through 10 September 1990.

	No. Caught	No. Harvested
Coho salmon	440	336
Pink salmon	30	12
Rainbow trout	21	1
Steelhead trout	4	3
Dolly Varden	90	23

Table 10. Age composition of coho salmon sampled from the Afognak Lagoon sport harvest, 1990.

SEX	AGE GROUP 1.1	2.1	3.1	TOTAL
Female				
Sample Size	4	32	1	37
Percent	11	86	3	
Male				
Sample Size	4	49	7	60
Percent	6	82	12	
Sexes Combined				
Sample Size	8	81	8	97
Percent	8	84	8	

Table 11. Mean length (millimeters) of coho salmon sampled from the Afognak Lagoon sport harvest, 1990[a].

	AGES			
	1.1	2.1	3.1	Total
Females				
Mean Length	603	613	638	613
Range	563-632	544-652	638-638	544-652
Sample Size	4	32	1	37
Males				
Mean Length	583	628	636	626
Range	483-637	498-690	610-671	483-690
Sample Size	4	49	7	60
All Fish				
Mean Length	594	622	636	621
Range	483-637	498-690	610-671	483-690
Sample Size	8	81	8	97

[a] Mid-eye to fork-of-tail length.

DISCUSSION AND RECOMMENDATIONS

Coho salmon escapements have averaged about 10,000 fish since consistent documentation began in 1984. The 1990 escapement of 13,380 fish appears to be healthy and is only 467 fish lower than the 1985 record escapement, a year in which the weir was operated 12 days longer than in 1990. The 1990 estimate is a minimal value since some immigration undoubtedly occurred after the weir operation was discontinued. Commercial and subsistence fisheries managers have established an escapement goal of 8,000 fish to be achieved by 15 September. This goal has been nearly achieved in all years since coho salmon have been monitored in this system with the exception of 1986. The current bag limit appears to be appropriate in that it allows for a consistent and stable fishery to be prosecuted without necessitating frequent closures to achieve escapement objectives. The current bag limit of up to 5 coho also allows more harvest opportunity than in heavily fished road system areas where escapement objectives can be jeopardized by intensive sport fishing.

Afognak coho salmon will school and hold in the lagoon during periods of low waters, during which time they are vulnerable to sport fishing harvest. To date, it does not appear that the sport harvest has adversely affected escapement. However, there is a possibility that during a low water year coupled with a weak coho run, sport harvest could impact the desired escapement.

Although no regulation adjustment to the bag limit is warranted at this time, sport fishery managers should monitor the daily Afognak coho escapement. If escapements are lagging, buildups in the lagoon should be monitored. If the run appears to be weak, restrictions in the sport fish harvest may be necessary to achieve escapement goals.

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